PREDICTION OF A SEQUENTIAL SHORT-TIME OD MODEL BASED ON PERSON TRIP DATA IN AN URBAN AREA

Yoshitaka KAJITA
Research Associate
Dept. of Urban and Environmental Eng.
Kyushu University
Hakozaki, Higashi-ku, Fukuoka,
812-8581 Japan
Fax: +81-92-642-3278
E-mail: kajita@doc.kyushu-u.ac.jp

Satoshi TOI
Associate Professor
Dept. of Urban and Environmental Eng.
Kyushu University
Hakozaki, Higashi-ku, Fukuoka,
812-8581 Japan
Fax: +81-92-642-3277
E-mail: toi@doc.kyushu-u.ac.jp

Yuho KUBO
Doctor course
Dept. of Urban and Environmental Eng.
Kyushu University
Hakozaki, Higashi-ku, Fukuoka,
812-8581 Japan
Fax: +81-92-642-3278
E-mail: kubo@doc.kyushu-u.ac.jp

Hiroshi TATSUMI
Associate Professor
Dept. of Civil Engineering
Kyushu Sangyo University
Matsukadai, Higashi-ku, Fukuoka,
813-8503 Japan
Fax: +81-92-673-5692
E-mail: tatsumi@ip.kyusan-u.ac.jp

Abstract: In this paper, the structure of a time-of-day travel demand forecasting model system is discussed. A short-time Origin-Destination [OD] model is constructed to estimate traffic volume in each time class during a day. A short-time traffic assignment is also proposed considering some trips do not always arrive at a destination within the same time class and link into the next phase. Also, Sequential short-time modal split must consider traffic conditions of each time class. Therefore, joint modal split and assignment model is constructed. In these models, time distributions and trip-length are required. These models are analyzed considering differences in characteristics of trip purposes and personal attributes and estimated by model parameters from the Person trip survey data.

Key Words: Short-time OD, Joint modal split and assignment model, Person trip survey

1. INTRODUCTION

The traffic congestion is a serious social problem in itself. In addition, it makes the problem like traffic accidents and the pollution. The measures to clear up the traffic congestion are the improvement of the existing traffic facilities or that expansion, flextime system and a multi-modal shift measure. Then, it is necessary to clear on the phenomenon on a time class like the traffic congestion but also the time jitter at whole forecasting system in order to analyze the effects of these measures. And so, it is necessary to consider the time-of-day travel demand forecasting model system expanded the four-step model on a day.

In addition, the declining birth rate and aging society are a serious problem in Japan. Of course, the model should respond to these changes in population structure. Differences for each personal attribute are often estimated as explanation variables, and the differences are given by linear structure for most models. However, because an activity is varied by personal attributes such as gender, age or occupation, it is necessary to organize a model based on those characteristics of time-fluctuation because of those differences. Also, Trip-length was a significant variable consistently occurring at the OD model to traffic assignment and an explanation variable of the time therefore it was necessary to analyze along with time-fluctuations. Here, trip-length in this paper means the travel time between zones.

The purpose of this study was to construct a time-of-day traffic demand forecasting system considering the characteristics of time-fluctuation and trip-length in trip purpose and personal attributes. Firstly, a short-time Origin-Destination [OD] model is constructed to estimate traffic volume in each time class during a day. Then, time distribution and trip-length are analyzed considering differences in characteristics of trip purposes and personal attributes. Next, joint modal split and assignment model is constructed considering some trips do not always arrive at a destination within the same time class and link into the next phase.
A time-of-day traffic assignment is the conventional method to predict the temporal evolution

of the congested network flow. This method usually needs time-of-day OD tables as a first step. Matui *et all* (1991, 1992) proposed forecasting method concerning the time-of-day OD table. However, the time-of-day OD model was relatively rough. The time distribution for each OD is temporarily given, in which a classification of trip purposes and differences of each personal attribute are not enough.

We have previously studied the distribution of originating time of trips at intervals of 30 minutes (Kubo *et all* (2001)). The differences of distributions for each trip purpose and personal attribute were cleared up. An interval for the distribution of originating time from the person trip [PT] survey required at least 30 minutes, and so we called the time-of-day OD in 30 minutes intervals as a short-time OD. But the constructed time distribution model was incomplete in regard to the zone-related index. Models are constructed using the 3rd Person Trip Survey of the Fukuoka urban area and the Population Census (1995). The population census data was used to explain variables of models. The Fukuoka urban area is shown in Figure 1. There were 27 zones in B-zone unit. This zoning is a municipality unit and the minimum unit to estimate model parameters.
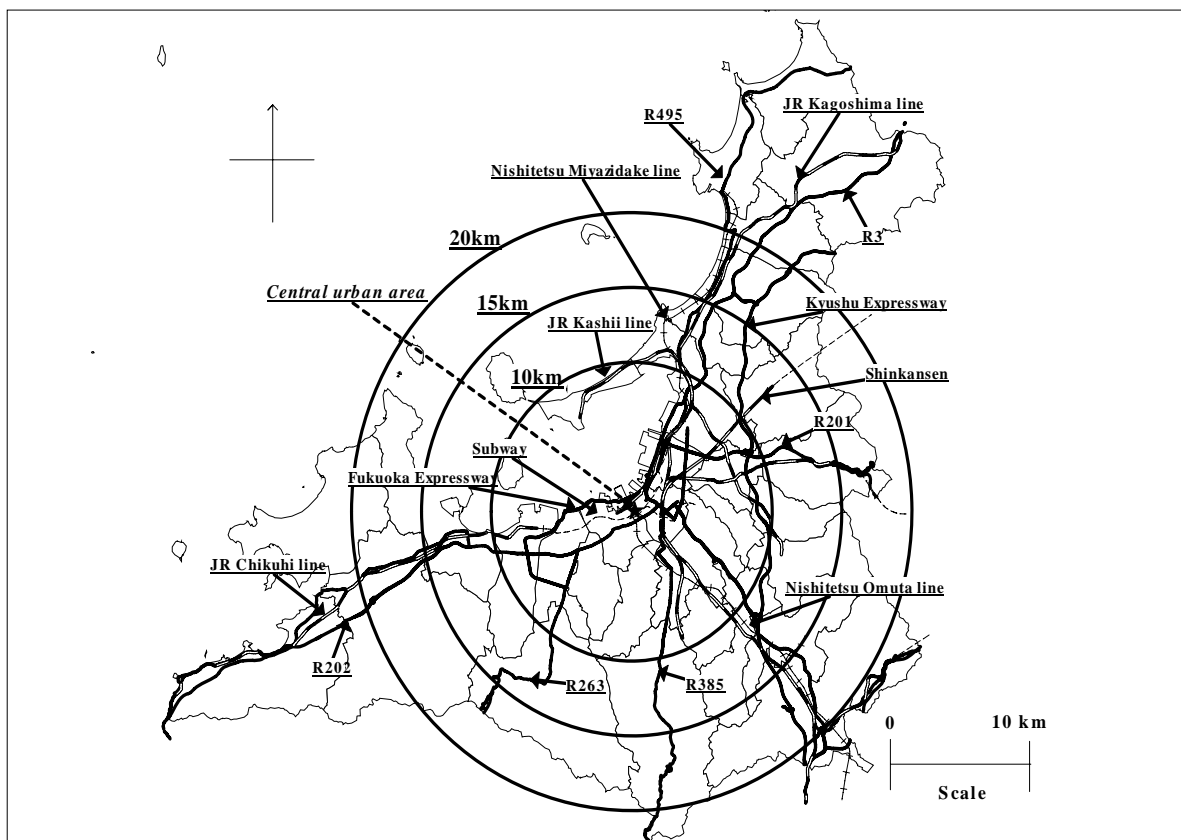

Figure 1. Fukuoka Urban Area

2. TRAVEL DEMAND MODEL SYSTEM OF SEQUENTIAL SHORT-TIME

A model system as an expansion on the conventional four-step model is proposed because it is used widely in business and works well for the analysis of each step. Considering the focus of this study, the factors of the time-fluctuation of each step and the characteristics of departure time distribution were the top priority.

The four step model can be divided two groups: a) a description of the number of trips: trip productions model and trip generation and trip attraction model, and b) a description of trip pattern: OD model, modal choice model and traffic assignment model. The number of trips is usually forecast day-to-day from an availability of explanation variables and, OD distribution pattern is no different for time categories; therefore, in this study, sequential short-time OD trips were also treated as the pattern of time-fluctuation in a day from the viewpoint of a function of model and characteristics of time distribution.

Travel time between zones was assumed at random based on a trip-length distribution for each zone in each mode. The trip-length distribution estimated remaining trips on a network link where a time class changed to the next phase and a short-time modal split and traffic assignment. Concept of proposed model system is shown in Figure 2.
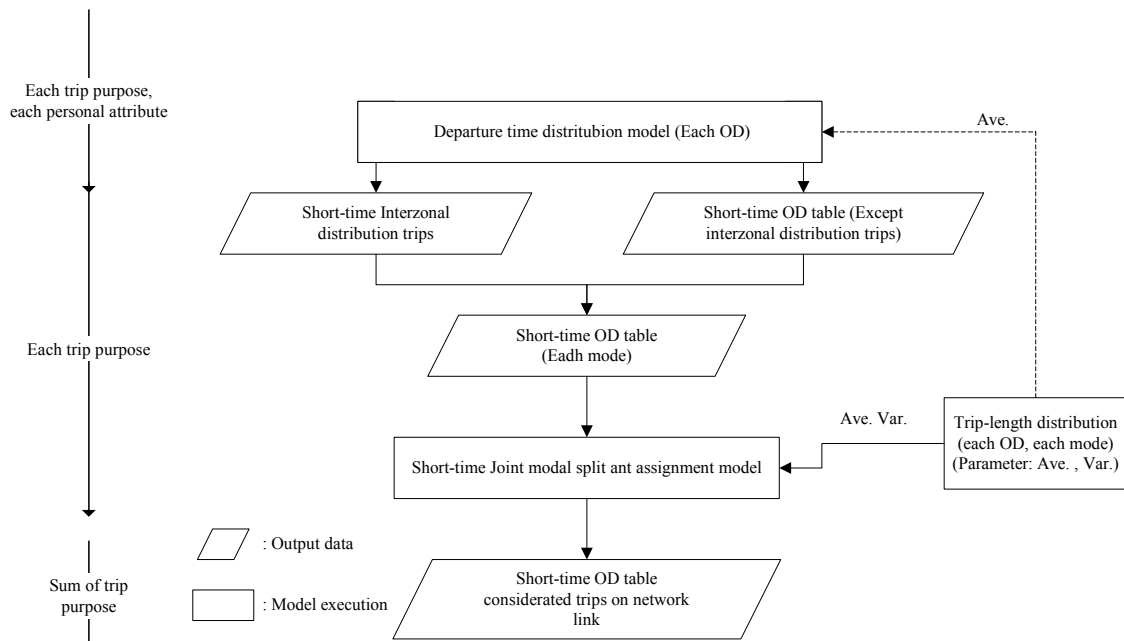
Figure 2. Concept of Proposed Model System

3. TIME DISTRIBUTION

3.1 Characteristics of Time Distribution

The characteristics of time-fluctuation were considered by a time distribution of 30 minute intervals between 3:00am and 3am. The analysis of time and trip-length distributions was made on the cluster correlation analysis and also the Kolmogorov-Smirnov test. The following analyses were based on this classification. An outline of time distributions for each trip purpose is shown in Figure 3. Then, trip purposes and personal attributes are classified in Table 1.
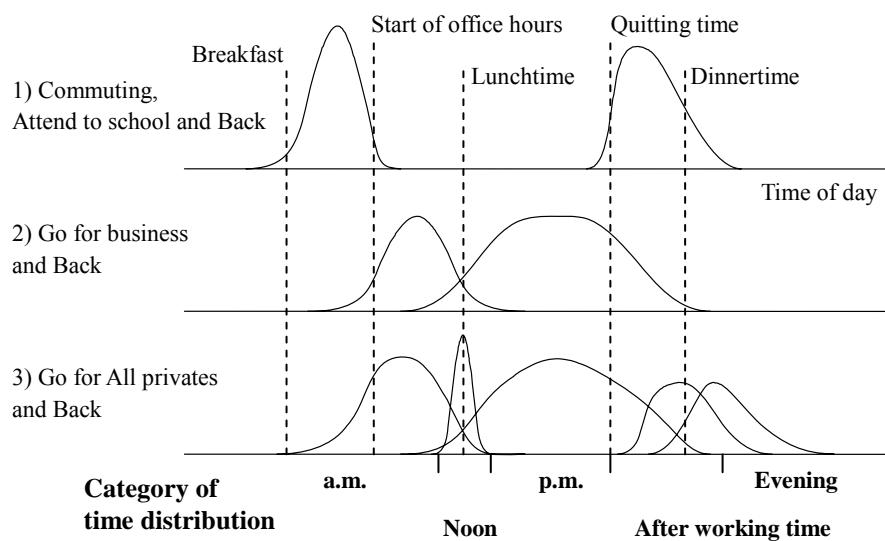
Figure 3. Outline of Time Distributions of Each Trip Purpose

Table 1. Classification of Trip Purposes and Personal Attributes

Trip purpose	16 groups	1. Commuting, 2. Attend school, 3. Business
		4. Repair, 5. Other business, 6. Agricultural
		7. Shopping, 8. Recreation, 9. Go on another trip
		10. Return from work, 11. Return from school
		12. Return from business trip, 13. Return from agricultural trip
		14. Return from shopping, 15. Return from recreation
		16. Return from other trips
Sex	2 groups	1. Male , 2. Female
Age	3 groups	1. Young (under 15), 2. Middle (15-64), 3. Old (over 65)
Occupation	3 groups	1. Employed, 2. Student, 3. Unemployed (and Wives)

Time distributions were categorized into five groups (a.m., noon, p.m., after office hours or school, and evening) and time distributions with several peaks were considered an aggregate of probability distribution. Departure times were assumed at random. In addition, the analysis of linking trip purposes, the order of a trip and the number of production trips support this assumption. On the other hand, OD distribution patterns were no different between time categories so that using the time-of-day OD model was the same as a day OD model. Differences in time distribution were elicited mainly through trip purposes, occupations and zonal characteristics. Differences in gender and age were classified by the differences in activity time. These differences were small but it was necessary to be exact about factors producing peaks.

3.2 Time Distribution Model

Time distribution model are given by probability density function (PDF). The time distribution with several peaks is assumed to aggregate the PDF because it is appropriate to consider that a traveler decides a rough time of departure that corresponds to the distribution ratio.

$$X_{ij}^{Lk}(t) = X_{ij}^{Lk} \cdot F_{ij}^{Lk}(t) \tag{1}$$

$$F_{ij}^{Lk}(t) = \omega_{am}^{Lk} \cdot f_{am\,ij}^{\ Lk}(t) + \omega_{pm}^{Lk} \cdot f_{pm\,ij}^{\ Lk}(t) + \cdots + \omega_{eve}^{Lk} \cdot f_{eve\,ij}^{\ Lk}(t) \tag{2}$$

where $X_{ij}^{Lk}(t)$ = OD trips for time-class t between zones i and j for personal attribute L, and trip purpose k,

$F_{ij}^{Lk}(t)$ = the time distribution for time-class t between zones i and j for personal attribute L, and trip purpose k,

$f_{\bullet ij}^{Lk}(t)$ = the time distribution of each peak for time-class t between zones i and j for personal attribute L, and trip purpose k, and

$\omega_{\bullet}^{Lk}$ = the distribution ratio of time distribution for each peak ($1 = \sum_{\bullet} \omega_{\bullet}^{Lk}$). The

time distribution is categorized into five categories by each peak. Then the ratio varies in each personal attribute L and each purpose k.

The time distribution is approached by beta probability density function. In the time distribution of each peak, when the average is $\mu_{TD\,ij}^{\ Lk}$ and variance is $\sigma_{TD\,ij}^{2\ Lk}$, the PDF of beta distribution $f(x \mid a, b, t_{\min}, t_{\max})$ is expressed as follows.

A standard beta distribution's upper and lower bound is $0 \le x \le 1$, then the time-class t , the average and the variance of the time distribution are transformed as follows:

$$x = (t - t_{\min})/(t_{\max} - t_{\min}) \tag{3}$$

$$\mu = (\mu_t - t_{\min})/(t_{\max} - t_{\min}) \tag{4}$$

$$\sigma^2 = \sigma_t^2 / (t_{\max} - t_{\min})^2 \tag{5}$$

where $t_{\max}, t_{\min}$ = the upper and lower bounds for 48 time-classes,

μ_t, σ_t^2 = the average and variance for 48 time-classes, and

μ, σ^2 = the average and variance for beta distribution.

a and *b* are parameters.

$$a = \left\{ \mu^2(1-\mu) - \mu\sigma^2 \right\} / \sigma^2 \qquad (6)$$

$$b = (a/\mu) - a \qquad (7)$$

Table 2. Estimated Parameters (Averages of Time Distributions Using Regression Analysis to Select Explanation Variables)

	Correlation coefficient	upper bounds / lower bounds	Constant	sex (female=1)	Distance between OD	frequency of train service	frequency of bus service	Generated zone PCS No.1 departure frequency	Generated zone PCS No.2 suburb level	Generated zone Stations (existing=1)	Attracted zone PCS No.1 arrive frequency	Attracted zone PCS No.2 suburb level	Attracted zone Stations (existing=1)
p1e am	0.896	3:00 / -12:30	10.5 (145.4)	0.7775 (13.8701)	-0.0366 (8.1051)		0.0022 (5.1002)				-0.0438 (5.6443)		
p2y am	0.658	3:00 / -12:30	10.6 (122.3)			-0.0027 (2.5535)	0.0008 (2.1883)				0.0487 (3.6623)		
p2s am	0.688	3:00 / -12:30	11.7 (33.7)	-0.6189 (2.8794)	-0.1321 (1.9848)				-0.0749 (1.4187)			0.1803 (3.3883)	
p3e am	0.755	3:00 / -12:30	13.9 (32.4)	0.8642 (3.6543)	-0.0529 (1.5103)		0.0055 (2.5237)		-0.1824 (3.8226)			0.1063 (1.9554)	
p3e pm	0.569	11:30 / -02:30	24.4 (48.8)	-0.5591 (2.2031)	-0.1189 (2.7984)		-0.0063 (1.9220)				0.1382 (2.9940)		
p5e am	0.774	3:00 / -13:00	18.4 (32.8)	1.5392 (3.4507)						-0.8466 (1.4458)		0.1880 (2.8634)	
p5e pm	0.897	12:30 / -02:30	29.0 (40.6)	-2.2177 (4.4346)			-0.0094 (2.3167)		0.1639 (2.2888)				
p7e am	0.761	3:00 / -13:00	17.0 (77.6)					0.1548 (4.0631)					
p7e pm	0.636	12:00 / -16:00	22.5 (77.2)	0.9394 (2.8521)									
p7e ev	0.932	15:00 / -02:30	30.0 (70.8)	-1.4178 (4.7045)		0.0044 (1.6231)	0.0019 (1.4483)						
p7ue am	0.813	3:00 / -13:00	16.5 (96.7)			-0.0033 (2.0542)	0.0009 (1.2713)	0.0390 (1.6083)	-0.1692 (4.1250)			0.1937 (4.3188)	
p7ue pm	0.500	12:00 / -02:30	24.8 (149.1)									0.2534 (2.4476)	
p8e pm	0.536	3:00 / -16:00	19.5 (226.2)									0.0694 (1.9040)	
p8e ev	0.934	15:00 / -02:30	34.2 (72.6)	0.6010 (2.2138)	-0.3928 (3.8926)					-0.5909 (1.6669)		0.1903 (3.0822)	
p9e am	0.810	3:00 / -12:00	13.2 (44.2)	-0.8046 (1.9138)							-0.3892 (3.8741)		
p9e pm	0.467	11:00 / -15:30	20.9 (36.3)		0.2903 (1.8287)								
p9e ev	0.797	14:30 / -02:30	30.4 (152.5)	-1.0504 (3.7410)								-0.1185 (1.7659)	
p9ue am	0.559	3:00 / -12:30	13.7 (163.3)								0.0625 (3.3680)		
p9ue pm	0.463	11:30 / -02:30	23.0 (64.2)									0.1988 (2.0430)	0.5962 (1.4546)
p10e ev	0.871	15:30 / -02:30	31.5 (225.9)	-1.4759 (15.6527)			0.0029 (2.0991)	0.0574 (4.2445)			0.0257 (1.6545)		
p11s am	0.448	3:00 / -14:00	19.1 (103.9)					0.0746 (2.2968)					
p11s pm	0.807	13:00 / -02:30	28.0 (136.3)	-0.2346 (1.5010)			-0.0025 (2.9102)			-0.7144 (3.5357)			1.0119 (4.8053)
p14e am	0.323	3:00 / -13:00	18.0 (93.1)						-0.1353 (1.2752)				
p14e pm	0.751	12:00 / -16:00	24.1 (74.2)						0.3525 (3.0635)	-0.8779 (2.4320)		-0.2745 (2.1929)	
p14e ev	0.879	15:00 / -02:30	30.9 (64.1)	-1.5974 (4.6434)			0.0090 (3.6716)						
p14ue am	0.873	3:00 / -13:30	17.9 (135.6)			0.0063 (5.2081)	-0.0024 (3.1967)		-0.0838 (2.5020)	0.4358 (1.4796)			-0.5711 (2.2000)
p14ue pm	0.511	12:30 / -02:30	26.6 (258.0)						0.1694 (2.7275)				
p16e am	0.713	3:00 / -12:00	10.6 (11.0)				0.0287 (3.5240)				-1.7363 (1.9254)		
p16e pm	0.309	11:00 / -15:30	22.3 (73.6)									0.1877 (1.1695)	
p16e ev	0.748	14:30 / -02:30	35.8 (20.0)	-3.6501 (3.7980)	-0.6672 (1.5035)								
p16ue am	0.668	3:00 / -11:00	13.1 (36.2)			-0.0077 (2.0025)		0.1631 (3.2225)					
p16ue pm	0.666	10:00 / -13:30	17.5 (86.1)								0.7085 (3.1352)	0.1221 (1.9675)	

p: Trip purpose No. (See Table.1)
e: employed   am: A.M.   PCS: Principal Componet Score
ue: unemployed   nn: Lunch time
y: under 15   pm: P.M.
s: student(over 15)   ev: After working time (Intervals of each time category are differect un each trip purpose)

The time distribution is approximated by the above beta distribution for each OD between zone i-j and for each trip purpose. Then the upper and lower bounds $t_{\min}$, $t_{\max}$ are treated as a constant number ($t_{\min}$=3:00-3:29 (time-class 1), $t_{\max}$=2:30-2:59 (time-class 48)) based on the result of an analysis for some cases about values of the lower and upper bounds $t_{\min}$, $t_{\max}$. Estimating parameters are:

$$\mu_{TD_{ij}}^{Lk} = \mu = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_n x_n \tag{8}$$

$$\sigma_{TD_{ij}}^{2\ Lk} = \sigma^2 = \sigma_t^2 + p_\sigma \tag{9}$$

Explanation variables are a part of personal attributes and zonal characteristics. Hometown – workplace relationships and suburbs – urban relationship is first and second principal component scores based on a principal component analysis for generation trips of each trip purpose and attraction trips of each trip purpose. Explanation variables α_{ij} are basically given by the stepwise approach to regression analysis, but variables of personal attributes are used on all trip purposes as policy variables. Where there was no data, averages $\mu_{TD_{ij}}^{Lk}$ were assumed to have no differences in zonal characteristics, because coefficients of variation were few for every trip purpose and personal attribute. Variances had low correlations for almost all explanation variables, so errors between each variance were considered at random from the data analysis so that the variances were adjusted as equation (9). p_σ is the error distribution (the normal probability distribution: $\mu=-0.35$, σ^2=2.27).

Parameters of error distributions p_σ are given by residual errors of measured data. This error was considered a random factor that did not to show up on data, such as feeling, moods and accidents. Explanation variables of distribution ratio were unclear but a residual error of average distribution ratio for each OD was small: the average and variance of residual error is μ=0 and σ^2=0.0054; therefore, the distribution ratio is:

$$\omega_\bullet^{Lk} = \overline{\omega}_\bullet^{Lk} \tag{10}$$

where $\overline{\omega}_\bullet^{Lk}$ = the average distribution ratio of each trip purpose and personal attribute.
Some estimated parameters using the regression analysis are shown in Table 2. Incidentally, other estimated parameters are given by average values of time distribution for a trip purpose and a personal attribute, in other words, these are constant, so that there is no argument about a significance of an explanation variable. They were: a) long trip departure times were earlier than for short trips, and a departure time for a trip from a suburban district was earlier than from an urban district, b) departure times from a district where there were many trips were spread. The way of spreading was not always constant but it was likely to be either earlier or later in a day, c) a departure time from a zone with train stations was earlier than other zones but train users depart earlier than other mode users, and d) if trip-length rather than the distance between OD were used as the explanation variable, a future change in accessibility could be estimated, and it is also necessary to consider a future change of zonal characteristics of at least above trip purposes of each personal attribute.

Reproducibility of time distributions for some trip purposes based on the above estimated parameters is shown in Table 3. The reproducibility was excellent.

Table 3. Reproducibility of Time Distributions for Some Trip Purposes

	Correlation coefficient	Standardlized error ratio		Correlation coefficient	Standardlized error ratio
p1e am	0.992	4.7%	p10e ev	0.956	8.0%
p2y am	0.928	24.7%	p11s am	0.964	7.8%
p2s am	0.983	7.0%	p14 pm	0.981	4.4%
p3e am	0.978	4.2%	p14e ev	0.936	
p5e am	0.965	22.6%	p14ue am	0.989	4.3%
p5e pm	0.911				
p7e am	0.942	5.8%			
p7e ev	0.977				
p7ue am	0.973	6.7%			
p8e ev	0.978	7.4%			
p9e am	0.955	4.9%			
p9e ev	0.973				

p: Trip purpose No. (See Table.1)
e: employed
ue: unemployed
y: under 15
s: student(over 15)

4. SEQUENTIAL SHORT-TIME JOINT MODAL SPLIT AND ASSIGNMENT

4.1 Flow of this model

Joint modal split and assignment model is developed for considering modal split and trip assignment simultaneously. Because traffic conditions such as traffic congestion have an effect on both modal split and trip assignment. Estimation of trip assignment is after estimation of modal choice in traditional four-step model. Feedback is necessary. Sequential short-time modal split must consider traffic conditions of each time class. Therefore, joint modal split and assignment model is better than traditional separated model.

There are two types in Joint model. The one is Beckmann model, which is added imaginary link of mass transit in road network. Another is Nested logit model. The former can consider only one link of mass transit. But, it is easy to understand the change of mode share by time class in former model. Therefore, this study used the improved Beckmann model considering time class.
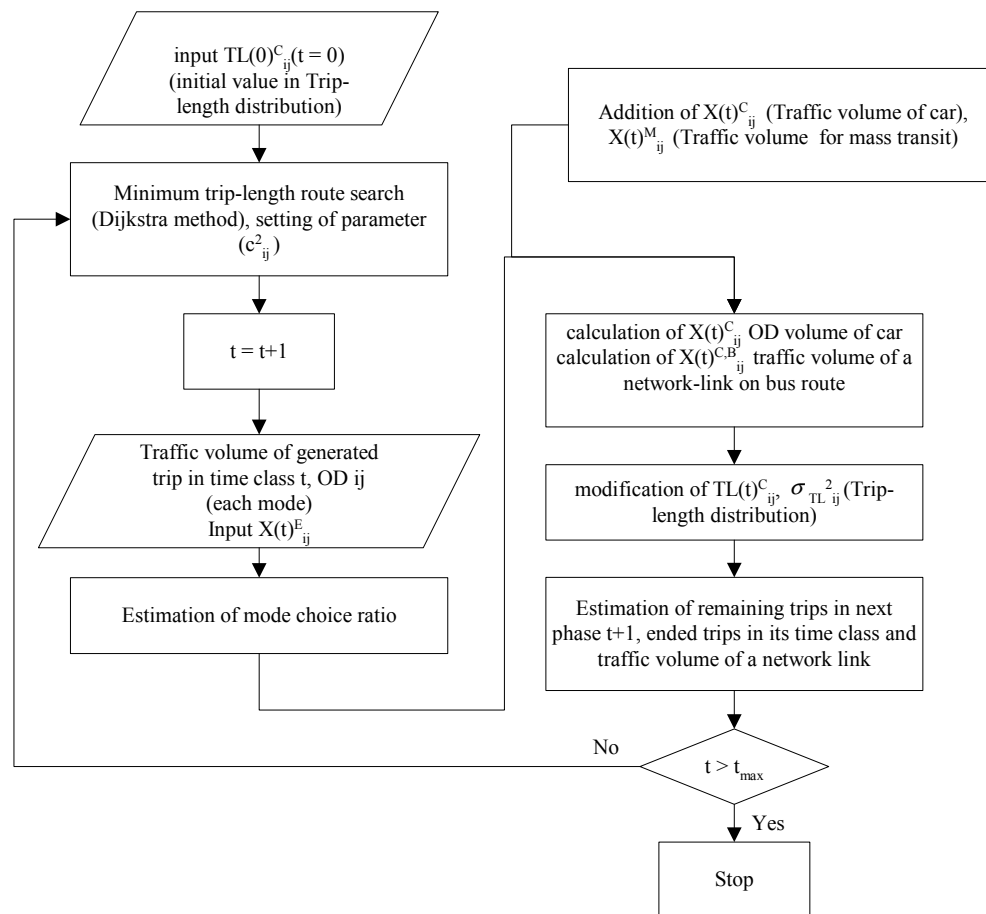

Figure 4. Flow of Joint Modal Split and Assignment Model

Figure 4 shows flow of joint modal split and assignment model considering time class. A conventional incremental assignment is basically applied. Characteristics of this model are two points. One is that generated trip is divided by time class. Another is that remaining trips on a network link where a time class moves into next phase are considered.

4.2 Trip-length Distribution

The four-step model requires the trip-length to estimate parameters. We used the trip-length distribution to estimate trips remaining on a network link and the travel time of alternative traffic modes. The length a person's trip was assumed at random and was given as the trip-length distribution for each OD pair and for each travel mode. There are no differences in trip-length for trip purposes and personal attributes. The trip-length distribution model is given by a lognormal probability distribution based on past analysis. Then these distributions

for car trip are consisted of average and variance models:

$$\mu_{TLij} = e^{\alpha 0} \cdot \lambda_{ij}^{\alpha 1} \cdot D_{ij}^{\alpha 2} \tag{11}$$

$$\sigma_{TLij}^2 = \beta_{\sigma 0} \exp(\beta_\sigma \cdot \mu_{TLij}) \tag{12}$$

where μ_{TLij} = the average of trip-length between zones i and j and for car, and

$\sigma^2{}_{TLij}$ = the variance of trip-length between zones i and j and car.

D_{ij} = the distance between zones i and j, and

$\alpha_\bullet, \beta_\bullet$ = model parameters.

λ_{ij} = density of traffic lights (number per km)

Moreover, these distributions for mass transit are consisted of average and variance models:

$$\mu_{TLij}^m = \beta_\mu \ln(D_{ij}) + \beta_{\mu 0} \tag{13}$$

$$\sigma^2{}_{TLij}^m = \beta_{\sigma 0} \exp(\beta_\sigma \mu_{TLij}^m) \tag{14}$$

where μ_{TLij}^m = the average of trip-length between zones i and j and for traffic mode m, and

$\sigma^2{}_{TLij}^m$ = the variance of trip-length between zones i and j and traffic mode m.

The PT data do not include cost data so cost variables were not used in this paper but some cost variables would be required to estimate the effect of measures. The reproducibility of model will be sufficient for use in the modal choice and traffic assignments. Estimated parameters for trip-length distribution and model reproducibility are shown in Table 4.

Table 4. Estimated Parameters for Trip-length Distribution and Model Reproducibility

	Variable	Car		
		parameter	t-value	judge
μ	α_1	0.2566	25.1	**
	α_2	0.1028	10.4	**
	α_0	0.3092	12.8	**
	multiple coefficient	0.941		
σ^2	β	-0.8237	13.9	**
	β_0	3.0023	5.9	**
	multiple coefficient	0.830		

	Variable	Mass transit		
		parameter	t-value	judge
μ	β	0.3857	13.3	**
	β_0	2.9900	43.6	**
	multiple coefficient	0.844		
σ^2	β	-1.5457	17.8	**
	β_0	33.6714	10.4	**
	multiple coefficient	0.902		

A conventional incremental assignment needs a capacity-restrained curve for each OD link. Then a performance function based on a trip-length - volume relationship is given by:

$$\mu'_{TLij} = \varphi \frac{X(t)_{ij}^C}{c_{1ij}} + \mu_{TLij} \tag{15}$$

where μ'_{TLij} = the adjusted average trip-length for traffic volume between zones i and j, and,

φ = the parameter.

$X(t)_{ij}^C$ = the traffic volume for car in class time t

c_{1ij} =coefficient of traffic capacity in OD ij

The parameter of φ is estimated using observed number of car trips in time class, according to using only the part of traffic assignment for car in Figure 4. The Optimum value of parameters are given by φ = 0.0013 using method of least based on Road Traffic Census data and PT data.

4.3 Estimation of Remaining Trips on a Network Link Where a Time Class Moves into Next Phase

When long-distance travel did not end in its time class, some trips stayed on a network-link into the next class. We proposed a modification method that used trip-length for each OD. A trip-length distribution between zones i and j is a probability passing through zone i. For example, when each trip-length distribution is given by $T_{ij}(\cdot)$, $T_{rj}(\cdot)$ and $T_{sj}(\cdot)$ where i is the origin zone, j is the destination zone, and r and s are link points between networks (See Figure 5), the probability that a trip that departed from zone i arrives at zone j within an elapsed time δt between a time t_1 and a time t_2 is given by:

$$T_{ii}(\delta t) \times T_{ir}(\delta t) \times T_{is}(\delta t) \times T_{ij}(\delta t) \tag{16}$$

And the remaining probability of trips on each link are given by:

$$1 - T_{ii}(\delta t) \quad \text{(On the link between zones } i \text{ and } r) \tag{17}$$

$$T_{ii}(\delta t) \times (1 - T_{ir}(\delta t)) \quad \text{(On the link between zones } r \text{ and } s) \tag{18}$$

$$T_{ii}(\delta t) \times T_{ir}(\delta t) \times (1 - T_{is}(\delta t)) \quad \text{(On the link between zones } s \text{ and } j) \tag{19}$$

Remaining trips on a link were treated as departures from the last zone in the next time class. In the case of equation (17), remaining trips depart from zone i in the next time class.
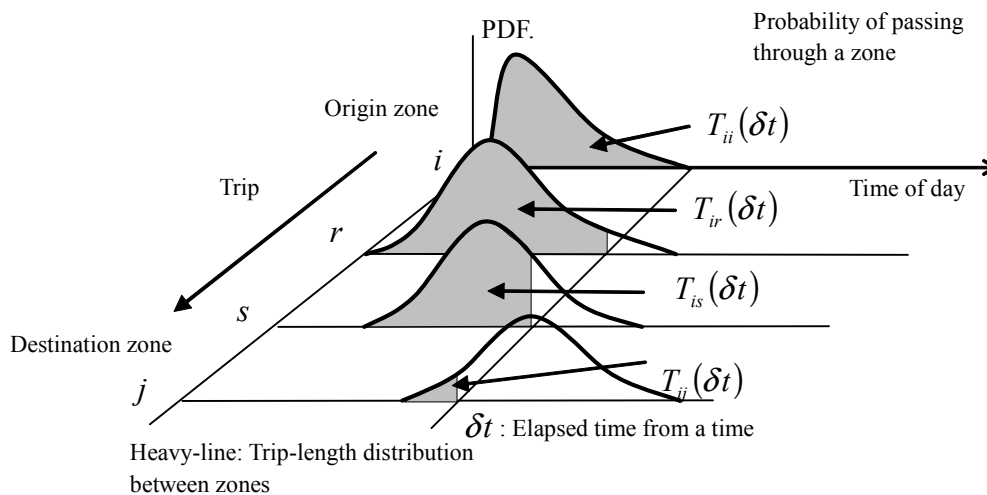

Figure 5. Concept of Passing Trips by Each Trip-length Distribution between Zones on a Network Link

4.4 Sequential Short-time Joint Modal Split and Assignment Model

In this study, traffic assignment model using difference of trip-length between mass transit and car is basically applied. Moreover, influences of car traffic volume to bus use are taken into considered in this model. Modal choice model of mass transit in time class t and OD ij is given as follows:

$$X(t)_{ij}^{M} = \frac{X(t)_{ij}^{E}}{1 + \exp\left\{ \theta\left(\alpha_1 \cdot TL_{0ij}^{M} + \alpha_2 \cdot X(t-1)_{ij}^{C,B} \middle/ S(t-1)_{ij} - TL(t-1)_{ij}^{C} \right) + \alpha_0 \right\}} \tag{20}$$

where $X(t)_{ij}^{E}$, $X(t)_{ij}^{M}$ =Number of trips for all mode in OD ij,

TL_{0ij}^{M} =trip length for mass transit (constant) ,

$TL(t)_{ij}^{C}$ =trip length for car,

$X(t)_{ij}^{C,B}$ =traffic volume for car on a link of bus use only,

$S(t)_{ij}$ =Number of mass transit in time class t (bus and train) ,

$\theta, \alpha_{\bullet}$ = parameter

If $X(t)_{ij}^{C'}$ is number of car trips in OD ij, storage conditions of OD is given as follows:

$$X(t)_{ij}^{C'} + X(t)_{ij}^{M} = X(t)_{ij}^{E} \tag{21}$$

$$X(t)_{ij}^{C} = X(t)_{ij}^{C'} \Big/ \overline{TC}(t)_{ij} \tag{22}$$

where $X(t)_{ij}^{C}$ = number of car-OD trips,

$X(t)_{ij}^{C'}$ =number of trips for car,

$\overline{TC}(t)_{ij}$ = average of riding person in time class t

On the assumption of user equilibrium, trip length for mass transit is calculated using equation (20).

$$TL(t-1)_{ij}^{C} = TL(t)_{ij}^{M}$$

$$TL(t)_{ij}^{M} = \frac{1}{\theta} Ln\left(\frac{X(t)_{ij}^{M}}{X(t)_{ij}^{E} - X(t)_{ij}^{M}} \right) + \alpha_1 \cdot TL_{0ij}^{M} + \alpha_2 \cdot X(t-1)_{ij}^{C,B} \Big/ S(t-1)_{ij} + \alpha_0 / \theta \tag{23}$$

According to equation (23), parameter is estimated using method of least squares. Parameters are $\theta = 11.7241$, $\alpha_0 = -36.8552$, $\alpha_1 = 1.5999$, $\alpha_2 = 0.00024$. Also, t-values are $1/\theta = 19.48$, $\theta/\alpha_0 = 31.71$, $\alpha_1 = 60.64$, $\alpha_2 = 3.71$.

4.5 Application of Model

Firstly, traffic volume on link and trip length for car is calculated by traffic assignment based on PT data. Secondly, Choice probability for mass transit is estimated.
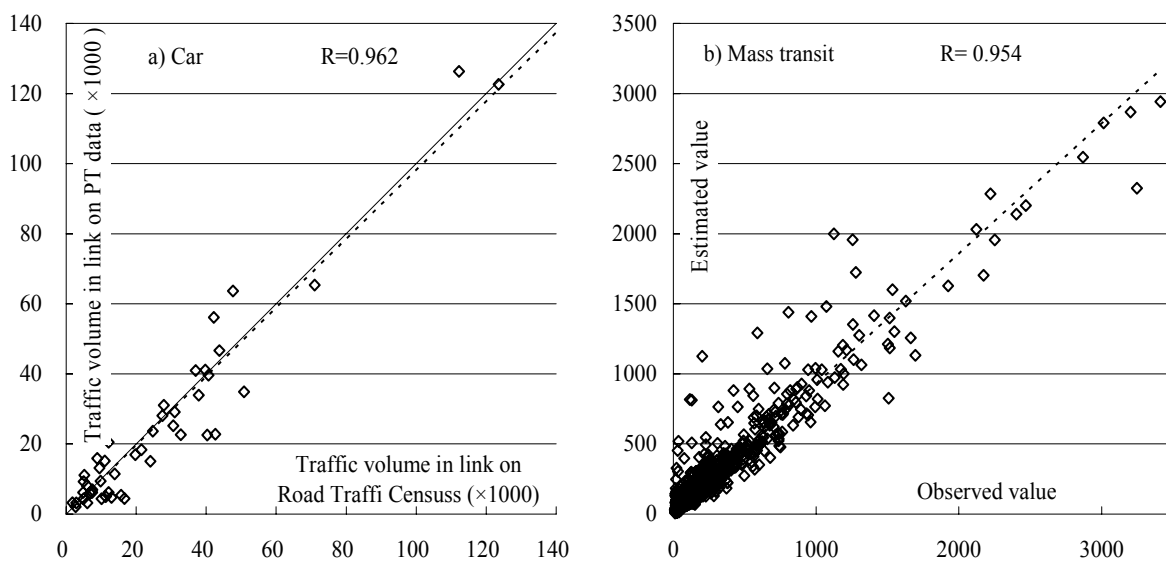

Figure 6. Result of Reproducibly of Traffic Volume

As a result of application, relationship between reproducibility based on PT data and Road traffic census data to car traffic volume for 12 hours on a link is shown in Figure 6.

Correlation ratio is 0.962 and standardized error ratio is 4.7%. Short-time traffic assignment for road is shown in Figure 7. Also, reproducibility of number of trips for mass transit based on the above estimated parameters and its observed number of trips is shown in Figure 6. Correlation coefficient is 0.954 and standardized error ratio is 1.4%. It is understood that precision of these models are high.

Notes : Numbers are traffic volume
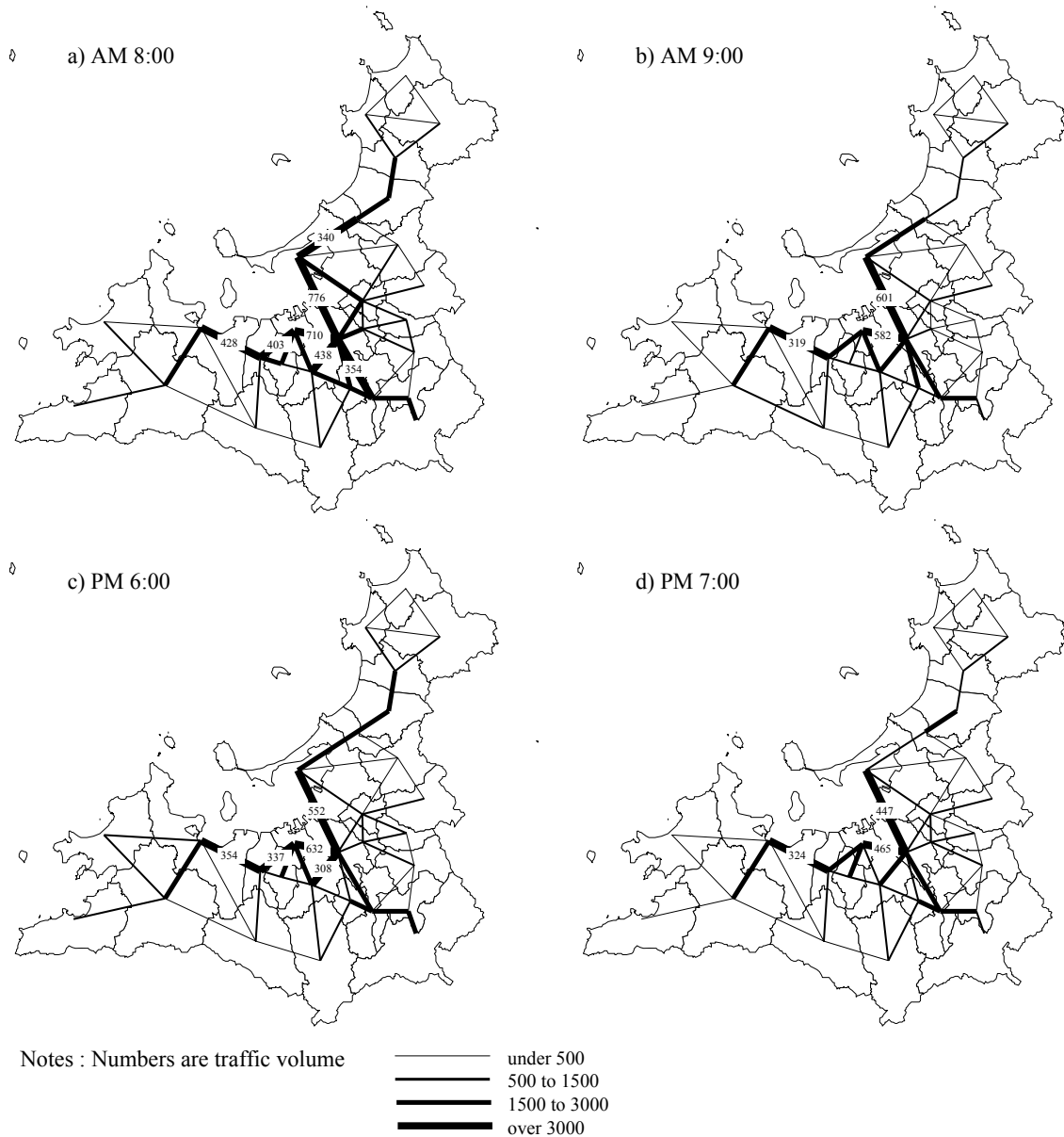
under 500
500 to 1500
1500 to 3000
over 3000

Figure 7. Result of Short-time Traffic Assignment for Car

5. CONCLUSION

In this paper, travel forecasting models for sequential short time are constructed in OD, modal split and traffic assignments. The, analysis of time distributions and trip-length considering differences in characteristics of trip purposes and personal attributes were estimated from the Person Trip survey data of the Fukuoka urban area. In conclusion:

a) The characteristics of time-fluctuation were considered by a time distribution of 30 minute intervals between 3:00am and 3am. Time distributions were categorized into five groups (a.m., noon, p.m., after office hours or school, and evening) and time distributions with several peaks were considered an aggregate of probability distribution. Differences

in gender and age were classified by the differences in activity time. These differences were small but it was necessary to be exact about factors producing peaks. The time distribution for each personal attribute and trip purpose is proposed by beta probability density function. The reproducibility was excellent.

b) We proposed joint modal split and assignment model. Because traffic conditions such as traffic congestion have an effect on both modal split and trip assignment. Also, sequential short-time modal split must consider traffic conditions of each time class. Therefore, joint modal split and assignment model is used. Then, trip-length distributions are analyzed considering differences in characteristics of trip purposes and personal attributes. Also, when long-distance travel did not end in its time class, some trips stayed on a network-link into the next class. Therefore, short-time joint model is necessary to estimate remaining trips on a network link where a time class changes to next class. Remaining trips on a network link where a time class moves into next phase are estimated.

c) Proposed sequential short-time joint modal split and assignment model are applied in Fukuoka Urban area. As a result, reproducibility of number of trips for car and mass transit are good. It can be said that precision of these models are high. This model can estimate traffic volumes between OD of the middle level as an OD between municipalities. Conventional traffic assignment is usually assigned at a network level of at least a local road. But, this model requires non-PT data like a road traffic census. Hence, the proposed method requires PT data only. From mentioned above, it can be said that short-time model using the trip-length of each OD is useful in practical use.

REFERENCES

Matui, H., Fujita, M., Kamiya, E. (1991) Forecasting Method of Traffic Generation/ Attraction and Distribution on Time-of-day Basis. **Infrastructure Planning Review**, **No.9**, 77-84, 1991.

Matui, H., Fujita, M., Kamiya, E. (1992) A Time-of-day Trip Generation/ Attraction Model Using Transition Matrices of Trip Purposes. **Papers on City Planning**, **No.27**, 367-372, November 1992.

Kubo, Y., Chishaki, T., Kajita, Y. and Kohara, T. (2001) Study on Trip Generation and Attraction Models of Travel Demand Forecasting based on the Structure of Time Distribution. **Journal of the Eastern Asia Society for Transportation Studies, Vol.4, No.3,** 191-205, October 2001.

Chishaki, T., Kusuda, M. Tatsumi, H. and Kikuchi, H. (1994) Spatial and Temporal Distribution Model of Car Trip. **Technology Reports of Kyushu University, Japan, Vol.67, No.1,** 17-23, January 1994.

Nakashima, H., Chishaki, T. and Kawano, M. (1987) Categorization of Traffic Purpose in Travel Demand Analysis. **Technology Reports of Kyushu University, Japan, Vol.60, No.6,** 695-703, December 1987.

Chishaki, T., Yokoyama, J., Tatsumi H. and Lee, S. (1994) A Study on a Modal-split Model of PT-survey Considered with the Mode's Usability for Each Pair of Zone and the Distribution of Trip-length. **Journal of Infrastructure Planning and Management, No.482/ IV-22,** 9-16, JSCE, January 1994.

Tujikawa, T., Matui, H. and Fujimoto, M. (1991) The Characteristic Analysis of Transportation Modal Choice in Hourly Variations. **Proceedings of Annual Conference of the Japan Society of Civil Engineers, Japan, Vol.46,** 342-343, September 1991.

Person Trip Data (1993) **Person Trip Survey**, Urban transport planning conference in Northern Kyushu area, Fukuoka, Japan

Population Data (1995) **Population Census**, Statistics Bureau and Statistics Center, Japan